NOAA Fisheries

Data Acquisition Plan

September 1998

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NOAA Fisheries Data Acquisition Plan

Executive Summary

NOAA Fisheries is charged with stewardship of the Nation's living marine resources through science-based conservation and management and promotion of the health of their environment. At-sea research and monitoring is the foundation upon which stewardship is based. This report responds to OMB's request for a data acquisition plan to outline how NOAA Fisheries' data requirements will be met over the next five years. The report deals with the interface of three highly dynamic systems: marine resources and their environment, the science and technology used to understand and manage them, and the policy arena that directs management and distributes fiscal resources. Linkages among these systems are robust; changes in one greatly influence the status of the others. Good planning is essential to the success of any mission, but planning for the future in this dynamic environment is particularly challenging. This Data Acquisition Plan (*Plan*) describes NOAA Fisheries' approach to provide the best possible information upon which to manage the Nation's living marine resources.

The *Plan* describes the evolution of NOAA Fisheries' mission, and its research fleet. Legislation which has influenced the stewardship process of marine resources, and its impact on data requirements is discussed. Changes on the horizon, such as management philosophies and impending technological advances, which will influence the way resources are researched, monitored and managed in the future are evaluated. All these factors were considered as the *Plan* was developed to achieve the flexibility required to properly manage a dynamic system in a dynamic environment.

A complex web of diverse data feeds into the resource management process. The critical importance of fisheries-independent data, requiring at-sea research is discussed. The *Plan* covers how decisions are made on what data are needed, how the criteria for data quality and quantity are established, and what tools are required to collect data that meet these criteria in the most cost effective manner. Available research platforms are evaluated, including NOAA or other fishery research vessels (FRVs), chartered fishing vessels and university ships.

The *Plan* discusses several options to meet the data requirements which were analyzed by a multidisciplinary team from government agencies, academic institutions and private industry. They determined that a new generation of FRVs was needed. The central philosophy of the *Plan* is to construct a core fleet of purpose-built, dedicated FRVs, and integrate them with chartered vessels from the academic and private industry fleets. Acoustic quieting will reduce behavioral responses of species targeted in surveys and minimize noise interference to hydroacoustic signals. The ships must have the speed, power and endurance to allow acoustic and trawl surveys at the shelf edge. The ships must have adequate berthing to support a full scientific complement, and be configured to support laboratories, computers and multi-gear (e.g., trawl, longline, oceanographic) capabilities. Further, the ships must be available for fisheries missions for at least a decade to protect the integrity of long-term resource surveys. Lastly, their design should accommodate technology development and mission changes over their service lives.

At-sea data are now collected by the existing NOAA fleet using 1,877 days at sea (DAS), supplemented by 1,227 DAS of chartered university and private industry vessels. NOAA Fisheries convened a workshop of stock assessment and vessel experts to review the requirements for DAS and how they were determined. The study concluded that 9.3 ship years of FRV time, supplemented with non-FRV (e.g. fishing vessel, research vessel) charters, are needed to meet at-sea data requirements. The Plan calls for the existing fisheries vessels in the NOAA Fleet to be phased out as four purpose-built FRVs are constructed, deployed and calibrated for service. NOAA will collaborate with UNOLS and the private sector to develop a means of meeting the remaining ship needs with chartered vessels.

An external review of the Plan was performed, and the report was provided to NOAA Fisheries in May 1998. The report concluded that construction of a core fleet of purpose-built vessels is a good approach, that the FRVs, as designed, will be outstanding, will serve the nation extremely well as the core of a dedicated fisheries fleet for their full projected lifetime, and that the vessels are not overspecified. Further study of vessel acquisition management, ownership, and operation was encouraged, and NOAA Fisheries is engaged in those studies now.

NOAA bears the stewardship responsibility for the largest EEZ in the world, and to perform that mission, it must have the proper tools. New legislation, management philosophies and scientific advancements have created new opportunities to improve fisheries management. Providing appropriate support will enable NOAA to capitalize on these opportunities, to the economic benefit of the Nation and integrity of our ecosystems.

"Stewardship of living marine resources for the benefit of the Nation through their science-based conservation and management and promotion of the health of their environment"

—NOAA Fisheries Mission Statement

INTRODUCTION

The United States' Exclusive Economic Zone (EEZ) is the largest in the world, encompassing 1.7 times the area of the U.S. and territorial land mass (Fig. 1). Stewardship of the Nation's living marine resources and their habitat is the responsibility of NOAA Fisheries. Management of U.S. fishery resources is an extremely complex process, requiring the integration of basic and applied research, outputs of sophisticated stock assessment models, socioeconomic factors, and allocations among user groups to maximize the benefits of the resource to the Nation. At the very foundation of that process, however, are fishery resource data. The vision statement in the *NOAA Fisheries' Strategic Plan* calls for credible, high-quality science supporting the NOAA Fisheries mission and minimizing risk in management decision-making. Reliable, up-to-date, and accurate scientific information is required to ensure continued sustainable use of healthy stocks and to develop and monitor the progress of rebuilding programs for overfished stocks.

The types of data used in fisheries management are nearly as diverse as the list of organisms the data represent. Likewise, the data come from a wide variety of sources. Dock-side sampling programs gather data from commercial and recreational fisheries landings. Observers are placed on commercial vessels to obtain information on bycatch, which is not represented in dock-side landings. Satellites are used to obtain sea surface temperature and ocean color data. Vessels are chartered from private industry and universities for certain types of at-sea data collection. However, dedicated fisheries research vessels (FRVs), are the most critically important tool in NOAA Fisheries' marine resource data collection regime. Fully committed to fisheries missions, FRVs provide a consistently available research platform, protecting the integrity of long-term data sets. Purpose-built ships are multi-capable, allowing simultaneous biological and oceanographic sampling, and facilitating shifts among gear types. They meet safety,

laboratory and berthing, and endurance requirements.

Commercial and recreational fishing constitute a major source of employment and contribute significantly to the economy of the Nation. Commercial landings in domestic ports totaled 4.3 million metric tons (mmt) valued at $3.5 billion (ex-vessel) in 1996.[1] Maximizing the long-term potential yield of the Nation's fisheries is accomplished through the acquisition and interpretation of information, a commodity with intrinsic value, and with a cost associated with its acquisition. Management risk may also be given units of cost; it is the cost of making a management error in terms of lost scientific credibility and public confidence, lost revenues resulting from overfishing, and/or lost ecological integrity. Increasing the quantity and quality of information that feeds the management process comes at a cost, but also diminishes risk. It is incumbent upon natural resource policy makers, with input from stakeholders, scientists, and managers, to balance the cost of information with the risk of failing to build sustainable fisheries due to inadequate quantity or quality of information (Fig. 2).

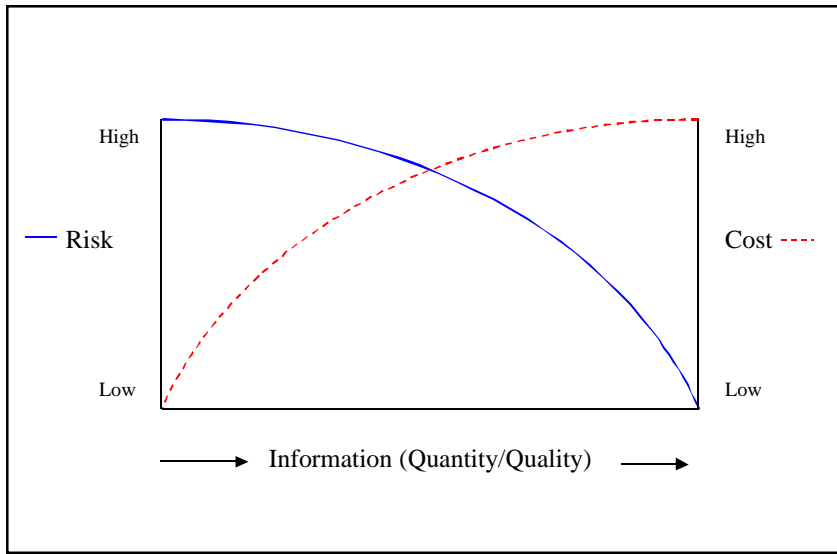**Figure 1.** United States Exclusive Economic Zone.

Figure 2.

Balancing the cost of obtaining information with the risk of management error due to inadequate information.

How much of an investment are we compelled to make in information accuracy and precision to offset the risk of making management errors which jeopardize sustainability of the Nation's marine resources? The objectives of this report are to: 1) identify overall data requirements; 2) illustrate how the requirements are prioritized; 3) examine alternatives and possible service providers to determine the most cost-effective means of meeting the requirements; and, 4) describe a detailed data acquisition plan to meet the data requirements.

This report sets the stage by discussing the history of the fleet and evolution of NOAA Fisheries' mission to put the existing status in context. Changes in legislation, management philosophy, and technological advances, and how they influence opportunities to improve fisheries management through increased data acquisition are reviewed. The variety of data required to properly manage marine resources and how they feed into the management process are outlined. A descriptive list of assets available to meet current and projected at-sea data requirements is given, and the appropriate mix of these ships and technologies, devised through planning and analysis, is presented. Finally, the *Data Acquisition Plan* and its implementation are discussed.

HISTORY OF THE FLEET AND EVOLUTION OF NOAA FISHERIES' MISSION

When NOAA was established in 1970, the Bureau of Commercial Fisheries, then renamed the National Marine Fisheries Service (NMFS), brought to the new agency 11 FRVs of varying age and condition. One of the primary missions of the agency then was fisheries development, directed toward exploring the potential of the Nation's underutilized fisheries, and the fleet of FRVs were adequate for that purpose.

Things have changed dramatically since then. During the 1970s, the development mission was largely phased out and stewardship legislation was enacted. As of December 31, 1996, 39 Fisheries Management Plans (FMPs) guided the use of 727 species of marine organisms. Of those species, NOAA Fisheries found that 86 (12%) were overfished, 183 species (25%) were not overfished, and 10 species (1%) were considered to be approaching an overfished condition. The status, relative to overfishing, of the remaining 448 (62%) species was unknown due to insufficient data.[2] In that same year, 855 regulatory actions were processed via the Federal Register, to implement FMP actions and rules for domestic fishing.[1]

At a time when FRV-based data demands to adequately manage, protect, and restore the Nation's fisheries are intensifying, NOAA's FRVs are fast approaching the end of their useful lives. Currently, the fleet consists of eight, dedicated FRVs, two-thirds time use of a NOAA survey ship and about 4-1/2 ship years of fishing industry charter vessels. Seven of the eight NOAA FRVs witnessed the formation of NOAA in 1970, bringing the average age of the vessels to over 34 years.

STEWARDSHIP LEGISLATION

New opportunities to improve stewardship of the Nation's living marine resources were created through changes to the agency's guiding legislation. However, capitalizing on these opportunities will require sufficient fiscal support. NOAA Fisheries operates under many laws and mandates; the three most important are discussed here.

Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA)

The MSFCMA has had a strong requirement for research since its passage in 1976 (16 U.S.C. 1801 et seq.).[3] The national standards required Fisheries Management Councils to manage fisheries for the optimum yield from each fishery, based on the best scientific information available. Subsequent amendments have strengthened the

scientific basis and requirements for managing the fisheries. The passage of the Sustainable Fisheries Act (SFA) in 1996, which amended the MSFCMA, has provided additional specific policy and management framework to prevent overfishing, rebuild overfished stocks, ensure conservation, facilitate long-term protection of essential fish habitat (EFH) and to realize the full potential of the Nation's fishery resources through a program for the conservation and management of those resources. The SFA provides, among other things, an additional national standard for bycatch, specific guidance regarding several scientific studies, and encouragement to expand annual assessments.

The amended MSFCMA now requires more stringent standards in the identification of overfished stocks within the EEZ and requires the revision of the definition of overfishing for practically every stock managed under an FMP. Overfished stocks, in turn, require rebuilding plans. Bycatch reduction and EFH must now be addressed specifically.

The amended MSFCMA stresses, more than ever, that collection of reliable data is essential to effective conservation, management, and scientific understanding of our fishery resources. In the face of an ever-growing list of stocks shifting from virgin or underfished to fully utilized or overfished status, and the overcapitalization of fisheries, information that was acceptable ten years ago is now inadequate for the effective management of fisheries. These situations, as in the West Coast and Alaskan groundfish fisheries, highlight the need for more and better research. These concerns were emphasized throughout the MSFCMA reauthorization process.

A solid scientific backing can reduce the unknown, refine the known, and provide a better analysis of the alternatives for management. Currently, the status relative to overfishing of approximately 60 percent of our stocks is unknown. Research can reduce that list, and help establish research priorities for stocks of concern. Better assessments can provide more accurate abundance estimates and better forecasts of future abundance, reducing the uncertainty in allocating quotas, and lowering the costs of following the precautionary approach. Better assessments also invoke more confidence from the fishing industry, encouraging better compliance with management measures. Better research in bycatch, EFH, life history, and ecosystems holds the promise for progressing from

reactive management towards adaptive management, allowing maximum catches with reduced risks for the fisheries.

The MSFCMA contains EFH provisions and mandates a supporting program to describe and identify EFH, to identify and evaluate actual and potential adverse effects on EFH (including both fishing-related and non-fishing related impacts), and to develop methods and approaches to conserve and enhance EFH. The ultimate goal of the EFH research described is to link fish productivity to habitat. This not only provides information for the protection, restoration and maintenance of marine habitat, but also advances our objectives to provide sustainable fisheries.

EFH research will focus on: 1) enhanced biological sampling to document life history, distribution and abundance of fisheries species, including habitat relationships to growth, mortality and productivity; 2) characterization of continental shelf and slope benthic habitats and the relationships between these habitats and the distributions and abundances of fisheries species; 3) identification of habitat that contributes most to survival, growth, and productivity; 4) identification of habitat important for recruitment; 5) determination and evaluation of adverse effects on habitat from point and non-point sources, harmful algal blooms, hypoxia, endocrine disrupting chemicals, and pathogens; 6) identification of impacts of fishing gear on habitat of managed species; 7) a test of the harvest refugia concept for selected areas and managed species; and 8) development of new methods and approaches for restoration of degraded habitats.

Lastly, the Secretary of Commerce was directed to establish a panel to provide advice on ways to incorporate ecosystem principles in fisheries conservation and management activities. The Panel, which will produce a Report to Congress by October 1998, is expected to call for expanded research on ecosystems.

Marine Mammal Protection Act (MMPA)

The primary goal of the MMPA is to maintain the health and stability of the marine ecosystem. Consistent with this objective, all stocks of marine mammals should be maintained within their optimum sustainable population levels. In keeping with this goal, the MMPA requires NOAA Fisheries to monitor the status of all seal, sea lion,

... new legislation created opportunities to improve stewardship ...

and cetacean stocks that occur in waters under U.S. jurisdiction. Stock assessment reports must include a description of the geographical range of the stock, information on the population dynamics of the stock, estimates of the total human-caused mortality by source, and estimates of the maximum level of direct human-caused mortality that the stock can sustain.

The statutory guidance for the quality of information included in stock assessment reports and in management decisions is to use the best available scientific information. However, maintaining up-to-date, high quality information on approximately 150 stocks of marine mammals is not feasible, and NOAA Fisheries must establish priorities for data collection under the MMPA. The consequences of using information or estimates with high uncertainty vary. Where human-caused mortality approaches or exceeds sustainable levels for depleted marine mammals, imprecise information could have a dramatic effect on the recovery of these stocks, or could result in major disruption of economically important activities potentially affecting the stock, particularly commercial fishing.

Endangered Species Act (ESA)

The principal purposes of the ESA are to conserve the ecosystems upon which threatened and endangered species depend and to develop programs for their recovery. These programs, including scientific research and management actions, may be conducted by state or federal entities, or through international agreements.

Embedded in the details of the law are several provisions that require research or monitoring to assess the status and trends of listed species and to identify and understand the various factors within the ecosystem that affect listed species. Specifically, the listing process requires scientific and commercial data regarding the status of species, effects of destruction or modification of habitat, effects of utilization, particularly overutilization, for various purposes (including incidental use), and the effects of disease, predation and other natural or anthropogenic factors affecting the species. Once a species has been listed, NOAA Fisheries must reexamine its status periodically to evaluate the continuing need for protection under the ESA. The ESA also encourages international cooperation in species research and cooperation as a commitment of the U.S. to the worldwide protection of threatened and endangered species.

From a fishery management perspective, the most consequential provision of the ESA is the requirement for federal agencies to consult under section 7, to ensure that federal actions do not jeopardize or adversely affect threatened or endangered species. This requirement means that NOAA Fisheries must have reliable information upon which to base a biological assessment of the effects of commercial fishing operations on listed species. The assessment of impacts upon listed species includes direct and indirect effects of fishing, and necessitates adequate status and trend information and an understanding of ecosystem processes.

Research and development of new technologies to mitigate or minimize the impacts of fishing operations require substantial scientific effort. The status of listed species is recognized as precarious; therefore, the need for reliable and timely information is critical. Where fishing operations overlap the distribution of threatened or endangered marine species, high quality information is essential to avoid management decisions that would be unnecessarily risky for the affected species or unnecessarily restrictive for the fishing fleet.

FUTURE OF AT-SEA RESEARCH AND MONITORING

As plans are made to replace the aging and technologically obsolete research fleet, it is important to understand how marine resource stewardship and the policies and technology to support it have evolved since the advent of NOAA, and how they may change in the future. For example, during the lifetime of the current fleet, NOAA Fisheries' focus has evolved from fisheries development to resource stewardship. Changes in data needs and advancements in the technology available to meet them have surpassed the capabilities of the current fleet. Careful planning will ensure that the new ships will be able to accommodate new needs and technologies over their 30-yr service life.

Living marine resources and the environments they inhabit represent profoundly dynamic systems, which introduces an element of uncertainty into their management. Many shifts in research and management approaches anticipated

over the next few decades are intended to deal with uncertainty. Precautionary principles established by recent UN agreements call for a more conservative balance between protection and sustainability of abundance levels versus maximizing catch levels.[4] Accounting for uncertainties must be addressed in each step of the management process, including management plan development, monitoring, research, stock assessment, and enforcement, and will impose additional demands on both quality and quantity of data. NOAA Fisheries has a plan in place to implement these principles into its management process, and vessel replacement is a component of that plan.[5]

The concept of adaptive management is being explored in fisheries research and management. In this concept, each change in management regulations may be thought of as an experiment with a hypothesized outcome. Only with sufficient data collection can the effectiveness of regulation changes (the results of the experiments) be objectively measured. This is particularly important with respect to stock-rebuilding plans, as required in the amended MSFCMA. Once a plan to rebuild overexploited stocks is implemented, adequate data to monitor its success are imperative to plan evaluation.

Marine reserves are being investigated as a means of hedging against recruitment failures, management errors, and for use as controls in comparisons of exploited to unexploited resources and habitats. Expanding spatial coverage of standardized stock abundance surveys to help study the merits of marine reserves are supported by the NRC review.[6]

Ecosystem approaches to management have caught the attention of Congress. There is a growing awareness among fisheries scientists and managers that such approaches may offer advantages over traditional single-species approaches for the development of more sustainable fisheries. Ecosystem approaches require significantly more information including marine environmental data

"... the absence of adequate data is the primary factor constraining accurate stock assessments. .... Thus, if future stock assessments are to avoid some of the past problems, management agencies must devote the necessary resources to monitor and investigate fish populations in a stable research environment that fosters creative approaches."[4]

—National Research Council Ocean Studies Board 1998

and information on species that may be the predators or prey of target species. To provide this increasingly complex information base, NOAA requires a new generation of vessels that are capable of collecting synoptic oceanographic and meteorological data along with information on fish, protected species, and their habitats.

NOAA Fisheries will continue to meet at-sea research and monitoring needs with a plan that fully capitalizes on available assets. Partnerships are an integral part of NOAA's current at-sea research program, and will have an expanding role in the future. One of the five major fishery research goals established in NOAA Fisheries' *Strategic Plan for Fisheries Research* is to improve the effectiveness of external partnerships with fishers, managers, scientists, and other interested groups to build a balanced approach for addressing fisheries research. Partnerships established to meet at-sea research and monitoring requirements, and to advance the science used to meet NOAA Fisheries' stewardship mission, are numerous and diverse. Among the five Fisheries Science Centers, partnerships with at least 48 academic institutions, 21 state organizations, 15 private industry organizations, 22 international entities, and 25 other federal organizations have been identified (Appendix A). Partnerships to accomplish at-sea data collecting will expand in the future, with chartered vessels conducting a growing proportion of at-sea work.

The *Plan* provides both the reliability and flexibility required to meet current research and monitoring program needs, while keeping an eye to the future. The fisheries management arena is a dynamic system; the resources are inherently variable and changes in technology, policy, legislation, and economics all influence the management process. This *Plan*, which couples a core fleet of dedicated FRVs with the use of chartered vessels, is designed to be responsive to changes in the biotic, physical, chemical, and human components of this dynamic system (Fig. 3).
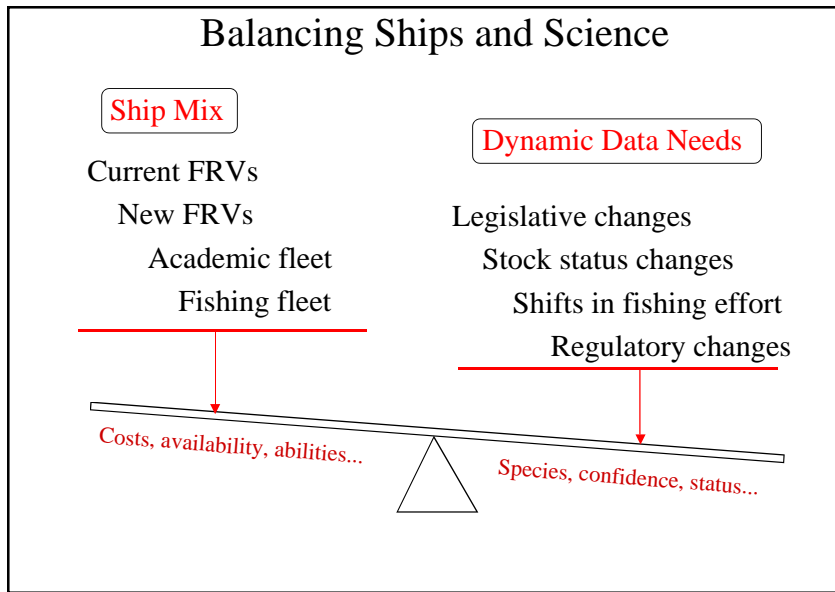
Balancing Ships and Science

Ship Mix

Current FRVs
New FRVs
Academic fleet
Fishing fleet

Dynamic Data Needs

Legislative changes
Stock status changes
Shifts in fishing effort
Regulatory changes

Costs, availability, abilities...

Species, confidence, status...

Figure 3.

The vessel replacement plan is flexible to allow changes in the ship mix in response to dynamic data needs.

DATA REQUIREMENTS

Requirements for at-sea research and assessment data will be detailed in this section by examining two important facets, data quality and quantity. First, the many types of data needed, how they feed into the management process, and their relative importance will be discussed. Then, the process through which survey duration and frequency, driven by statistical confidence criteria, are determined for individual missions. Finally, a discussion of how data needs are prioritized will be addressed.

What Kind of Data?

The types of natural resource data necessary to ensure sustainable use of living marine resources are nearly as diverse as the list of organisms they represent. However they can be divided into categories: 1) stock abundance; 2) exploitation — commercial and recreational fisheries; 3) life history parameters; 4) ecological/ecosystem relationships; 5) recruitment research; and, 6) synoptic oceanographic sampling. Each of these classes of information are valuable to the management process, and obtaining each type requires a unique strategy.

Data from each of these sources are essential to NOAA Fisheries' stewardship mission and form the foundation of the management process (Fig. 4). Data assimilation and analysis for fisheries management varies greatly among the stocks managed through FMPs, but the overriding sci-

entific principles are the same. Long-term trends in stock abundance indices allow population sizes to be tracked. Landings data allow fishing mortality rates to be calculated. Data on life history parameters enable population demographics to be monitored over time, which is essential to predict population responses to management changes. The process through which new year-classes recruit to a population is studied by sampling for eggs, larvae and juveniles within the ecosystem context. This requires data on relationships between climate and the currents which influence pre-recruit distribution, predator and prey species dynamics, habitat requirements, etc. Each of these types of data and how they are used to manage fisheries is described in detail below.

Biological, physical and chemical data are integrated into models that describe, and, when possible, predict stock status. Results of this process are used to determine levels of fishing mortality that allow long-term sustainability. Socioeconomic factors are incorporated into the process to develop harvest strategies that allocate the harvestable surplus among stakeholders. The quality and quantity of the data upon which this process is based greatly influence the likelihood of maximizing economic benefits of the Nation's living aquatic resources over the long term.

Stock Abundance

One reason fisheries management continues to be challenging, expensive, and contentious is that the most important type of information necessary to meet management demands is so illusive: a measure of stock abundance. To know how much of a stock can be harvested while still ensuring its long-term sustainability, it is necessary to know how many organisms comprise that stock. It sounds basic, yet consider that estimating stock abundances often requires enumerating a moving target in an open system that is huge, fluid, three dimensional, and generally out of sight. The approach to this problem has been to conduct fishery-independent surveys to develop an index of relative stock abundance. Ideally these surveys are conducted using standardized gear, vessels, and temporal and spatial coverage to maximize the validity of trend analyses.

Target species, habitat, and the life stage being surveyed all determine the most appropriate survey method and platform type. All of the following methods rely on the use of ships. Bottom trawls are used to measure abundance of demersal

fishes such as rockfish. For marine mammal species, visual counts along a line transect are made. Surveys of eggs and larval fishes are conducted to estimate spawning stock biomass of species such as sardines, herring and anchovies. Hook and line methods are used for species such as tunas and sharks. Hydroacoustic surveys are used to develop stock abundance indices for midwater species such as pollock and whiting.

Collection of stock abundance data on fishery-independent cruises is critical to minimizing bias. This fact was reinforced in a National Research Council review of NOAA Fisheries' stock assessment methods, *"Fishery-independent surveys offer the best opportunity for controlling sampling conditions over time and the best choice for achieving a reliable index if they are designed well with respect to location, timing, sampling gear, and other considerations of statistically valid survey design. NMFS should support the long-term collection of fishery-independent data, using either the NOAA fleet or calibrated independent vessels. Diminishing the quality of fishery-independent data by failing to modernize NOAA fishery research vessels or by changing sampling methods and gear without proper calibration could reduce the usefulness of existing and future data sets".[6]*

Exploitation

Landings Data: Fishery landing statistics provide a measure of counts, biomass, and species composition of organisms harvested from stocks and allow fishing mortality rates to be cal-
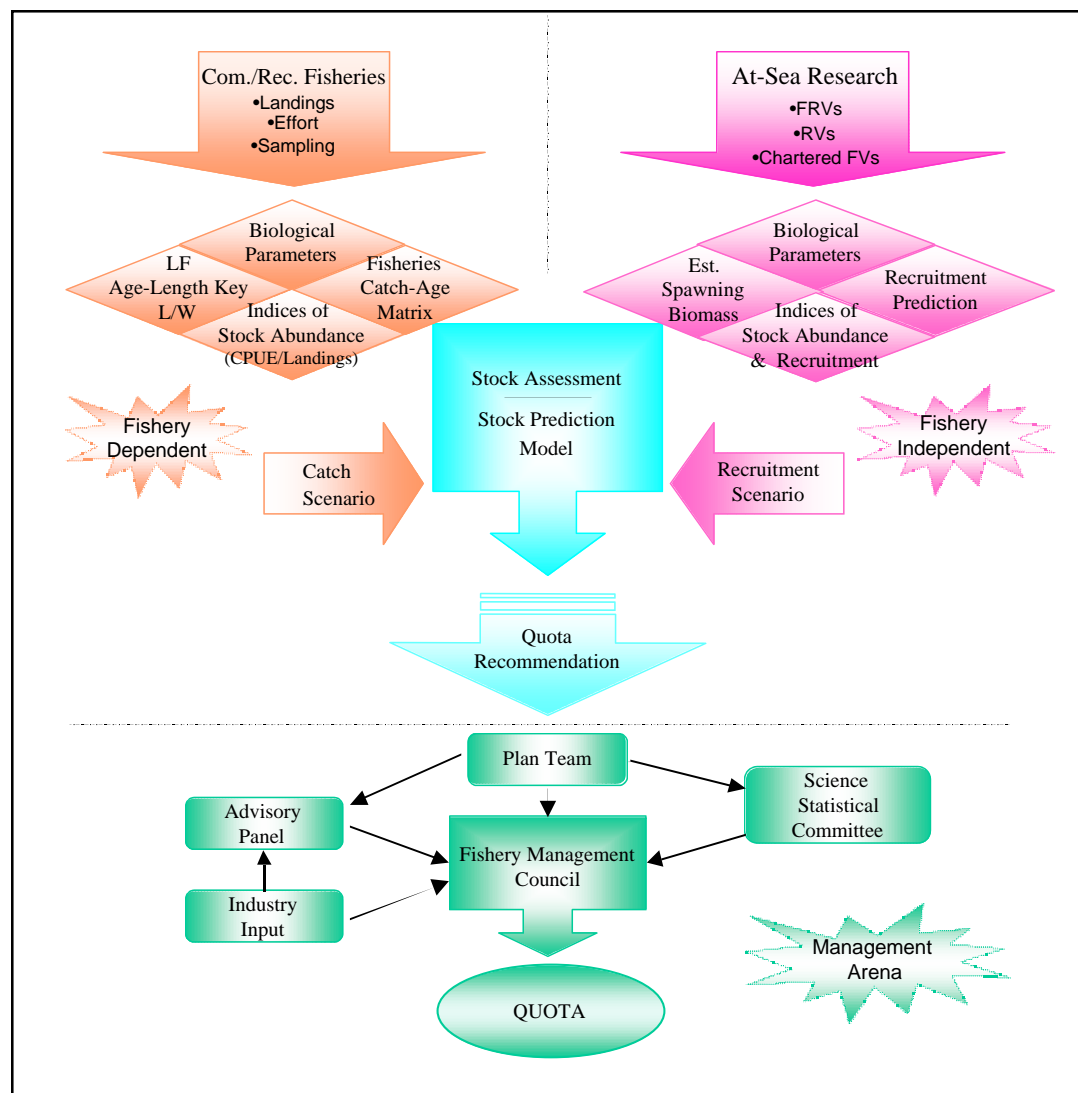

Figure 4. Flow of fishery-dependent and -independent data through the management process.

culated. These data are collected through a number of programs. dock-side sampling programs obtain data on actual landings. Logbooks, maintained by fishing vessel operators, provide additional data on the area of catch and the amount of fishing effort expended. Observers on board some fishing vessels verify logbook data and collect information on total catch, including discards and bycatch. Fishery catch-per-unit-effort (CPUE) is calculated from these data, but must be used with caution. Changes in fishing power (e.g. improved gear technology, use of satellite data to locate fish) and management regulations make standardization of effort difficult, rendering trend analyses invalid.

Bycatch Data: Approximately 27 million metric tons (30 million tons) of bycatch are discarded each year in the world's fisheries, compared to a total of about 77 million metric tons (85 million tons) of landed catch[7]. In 159 distinct U.S. fisheries, bycatch discarding affects at least 149 species or species groups.[8] Finfish, crustaceans, and mollusks comprise a majority of these species or species groups, while protected species such as marine mammals, sea turtles, and sea birds make up most of the remainder. Scientists are concerned about the effects that large-scale removals of certain species, age, and size classes have on the sustainability of fishery resources and on the functioning of marine ecosystems. From an economic perspective, there is concern that bycatch precludes better uses of living marine resources. Further, there are ethical concerns about bycatch's potential waste of protein resources and associated failure to fully utilize harvested living marine resources. The MSFCMA responded to these concerns with a new National Standard which states: *Conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent that bycatch cannot be avoided, minimize the mortality of such bycatch.* This standard constitutes the overall guidance and direction on bycatch for U.S. fisheries.

... at the very foundation of the management process are fisheries resource data ...

To properly address bycatch, conservation engineering research is needed. Chartered vessels continue to play a key role in the development of gear, gear modifications, and fishing practices to reduce bycatch. This research rarely demands long-term vessel continuity or specialized vessel requirements beyond what can be found in current commercial fishing fleets. Chartered vessels are actually preferred, since the goal is to duplicate commercial fishing operations. The success of this research relies on existing industry expertise and reflects NOAA Fisheries' commitment to maximizing the research contribution of the fishing industry and other non-government participants.

Life history parameters

Life history data are key to determining the rate of exploitation that a fish stock can sustain. Data on the age and sex composition, age at first maturity, fecundity, reproductive seasonality, mean generation time, and natural mortality rates of populations of organisms are collected by means of fishery-independent surveys. These data are used as input into stock assessment models that estimate total allowable catch (TAC) levels. The goal is to maximize economic benefits to the Nation, while ensuring long-term sustainability. Collection of life history data from landed specimens determines the degree to which gear/fisher selectivity changes the species, age, sex, etc. composition of the catch relative to the stock.

Ecosystem Approaches

A basic premise of ecosystem-based management is that relationships between resources and the ecosystems within which they exist must be well understood. This requires a more comprehensive approach to fisheries research than is necessary for traditional single-species management approaches. Recruitment and growth cause stock biomass to increase, and natural and fishing mortality cause it to decrease. In single species management, these four variables are often approached as though the species lived in a vacuum, unaffected by other species and its environment. An ecosystem approach is more holistic, allowing the stock's relationship to other species and to its physical environment to be considered (Fig. 5). Successful implementation of ecosystem-based management will require consideration of essential habitat requirements, hydrography, trophic relationships, and physical and biological processes.

Fishing affects ecosystems through: (1) bycatch and discards of nontarget species; (2) alteration of trophic relationships between target and nontarget species; and (3) alteration of habitat. In some cases, such as New England groundfish, fishing appears to have significantly changed the relative abundance of species in the ecosystem, and it is not clear that these changes are reversible. More information is needed to determine the long-term effects of fishing on all our fisheries ecosystems.
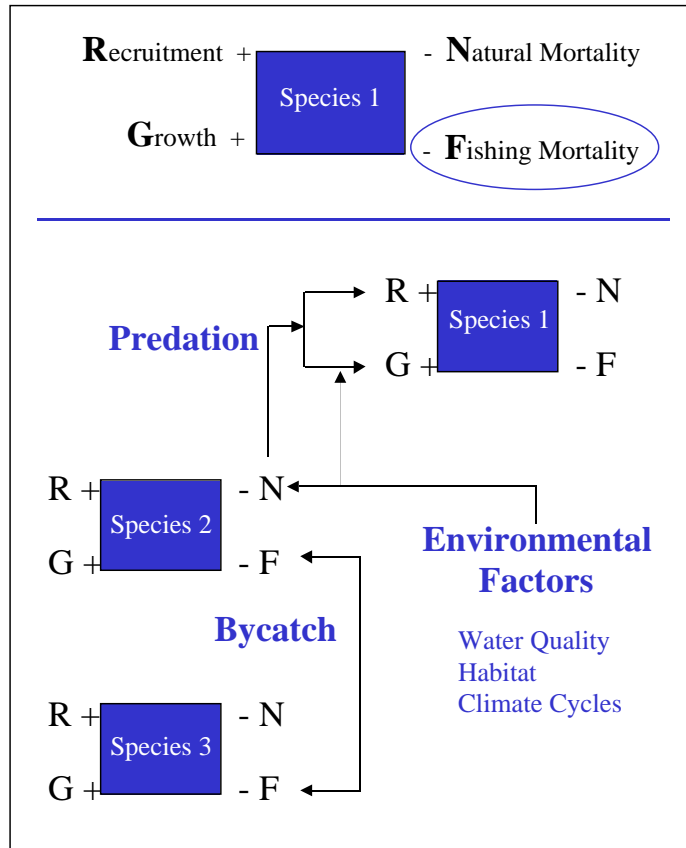
The SFA requires that the essential habitat needs of all species covered under FMPs be known. NOAA Fisheries scientists are currently using advanced technology such as submersibles and multibeam sonar, and geographic information systems to characterize and map the distribution of that habitat. NOAA Fisheries scientists are also working with the commercial fishing industry in several high-bycatch fisheries to estimate total biomass removals due to fishing, and to determine the impacts these removals may have on nontarget species and the ecosystem generally. To effectively implement ecosystem approaches to fisheries management, it will be necessary to know more about the habitat requirements of both target and nontarget species.

Process studies are critical to our understanding of the effects of environmental variability on fish growth and survival. These studies have been conducted in several key fisheries ecosystems (e.g., Georges Bank, Gulf of Alaska, Bering Sea), but have focused on a limited number of species on a very small spatial scale.

Recruitment Research

A major concern of fishery managers is biological overfishing which has two components; growth overfishing, and recruitment overfishing. Growth overfishing occurs when excessive fishing mortality co-opts future gains in biomass through growth. Recruitment overfishing implies a rate of fishing mortality that leads to there being insufficient new fish (recruits) to replace the parents who produced them. Thus, recruitment overfishing implies the depletion of the underlying spawning capital which produces fishery yields over the long-term.

To monitor recruitment, assessment surveys are typically conducted with sampling gear equipped with small mesh sizes that can capture very small animals. To predict future landings and stock sizes, estimates of the survival of fish already large enough to be retained by commercial gear must be combined with estimates of the incoming recruitment. Depending on the species, research vessel surveys can allow extrapolation of the strength of incoming age classes up to several years before they are legally allowed to be landed. For example, American plaice reach the minimum size for landing (14 in.) at about age 6. Fishery independent trawl surveys begin to sample American plaice during their first year of life, thus al-

lowing five estimates of the relative numbers of small plaice in the population before the animals are large enough to land.

Recruitment research seeks to reduce scientific uncertainty in management decisions by targeting the underlying physical and biological processes that influence the abundance of marine resource populations. This activity includes process-oriented studies that focus on 1) the causes of recruitment variability, 2) compensatory feedback mechanisms, and 3) species interactions among the trophic levels of predators and prey.

Recruitment is particularly relevant to short-term management decisions, such as setting a harvest limit (quota) on next year's catch. Often the recruitment estimate is the most tenuous information product used to set quotas. Compensation is more significant in the longer term. Because of the commingled sources of recruitment variability, it is often not possible to demonstrate or quantify the existence of compensation. This translates into greater uncertainty in quantifying the effects that management decisions will have. Species interactions are also relevant to long-term multispecies management. Very little is known

Figure 5.

Single species approaches (upper section) neglect the influences of factors such as species interactions, fishing effort, and environmental conditions on stock status that are captured in multi-species approaches (lower section).

about the indirect impacts fishery removals have on nontarget species, and on the ecosystem as a whole. In practice, species or fishery stocks continue to be managed as if they were biologically independent of all others. The continuing lack of progress in scientific knowledge of ecosystem relationships hampers progress towards the goal of true multispecies management.

Synoptic Oceanographic Sampling

Fisheries assessment cruises must include systematic oceanographic sampling. Information such as temperature, salinity and nutrients at depth, meteorology, plankton composition and biomass, and even currents is collected by vessels either on station or between stations. This information is needed to understand ecosystem functions and the ecology of the target and nontarget species, enabling predictions of future abundance to be made. Because these cruises are conducted on a regular basis, they also provide a low-cost means of monitoring long-term oceanic trends. Fisheries and oceanography agencies, including NOAA Fisheries, spend millions of dollars each year for the collection of such data, with a significant portion of that expense associated with vessel charter. By collecting these data concomitantly with ongoing assessment cruises, these costs can be minimized.

Regional Perspectives

Each of these types of data is a critical component of the total data needs to adequately meet the NOAA Fisheries mission and mandate. The U.S. Exclusive Economic Zone can be divided into six distinct ecosystems, Gulf of Alaska-Bering Sea, California Current, Pacific Oceania, Gulf of Mexico-Caribbean, South Atlantic, and North Atlantic. Additional research is also conducted in the Southern Ocean, per legislative mandate. Each of these ecosystems is unique, and as such, presents unique opportunities and challenges to management that promotes long-term sustainability (Appendix B).

How Much Data?

Development of a carefully reasoned strategy for determining survey duration and frequency is important for balancing data statistical criteria with acquisition costs. Meeting data precision criteria is essential to responsible stewardship of marine resources. Likewise, knowing the point of diminishing returns for survey duration or frequency by comparing improved precision with survey costs is essential to being good stewards of fiscal resources. The process by which survey duration and frequency are determined is discussed here.

Precision Issues

The duration of individual resource assessment cruises is primarily related to the need to sample populations intensively enough to provide meaningful information (i.e., with "acceptable" levels of precision and low potential for statistical bias) in the context of stock assessment and management. The frequency of surveys (numbers of surveys per year, decade, etc.) is determined principally by the rate of change in stocks (e.g., population size, recruitment), relative to how intensively species are harvested. It is impossible to estimate the relative or absolute size of populations exactly, given the enormous geographical scales and the sizes and numbers of species that are our targets. Thus improvements in precision must be balanced with the practical limitations of diminishing returns at very high (and expensive) sampling rates.

The precision and accuracy of information from resource abundance surveys are determined by the frequency of sampling units (discrete stations or miles of transect surveyed), and the degree to which the sampling gear can be deployed to efficiently encompass the geographic range of the target species or species group.[6] The relationship between the number of stations occupied (or transect miles sampled) and the precision of abundance estimators is an (nonlinear) increasing function. The relationship between sea days and effective sampling effort can be complex, owing to the logistics involved in steaming to, from, and between sampling locations, (i.e. there is an overhead of sea days that depends on the location of the first and last stations relative to home port).

Precision of survey abundance indices is routinely calculated for all NOAA Fisheries surveys (e.g., trawl and dredge sampling, line transects for marine mammal/turtle surveys, and hydroacoustic transect sampling). As an example, abundance indices based upon Northeast bottom trawl survey data for demersal species such as cods, flatfishes, etc. are more precise than those based on trawl catches of pelagic species such as herrings and mackerels (Fig. 6).

Estimates of sample precision are used directly when total population sizes of target animals are extrapolated from the sampled part of the population. When stock assessments are based on models of relative abundance over survey time series, precision of survey indices is a major component of the "goodness-of-fit" of such models.

What is the relationship between the precision of survey abundance indices and the numbers of DAS dedicated to a survey? This question has been comprehensively addressed by the Northeast Fisheries Science Center (NEFSC).[9] Spring and autumn bottom trawl surveys are conducted each year, and require about 48 DAS to sample the 250,000 km^2 area between Cape Hatteras, North Carolina, and the Gulf of Maine. Approximately 335 half-hour bottom trawls are completed in each survey, distributed according to a stratified random survey design. Assessment information is routinely generated for about 50 important resource species, and the survey provides information for 200+ species inhabiting the area. A measure of the precision of the abundance estimate for a species is the standard deviation (SD) of the catch per trawl haul (accounting for the location of stations within unequally sized strata). Abundance indices and their variability, as well as the relationship between sea days and numbers of stations completed were combined in an analysis relating the percent change in the SD of the abundance index to the change in DAS allocated to a survey (Fig. 7). These analyses show, over three major groups of species (demersals, pelagics, and flounders), that if DAS were reduced below the current level, the SD changes rather steeply, increasing by over 50% with an approximate one-third reduction in DAS. Conversely, by increasing DAS by one-third results in an approximate 20% reduction in SD. The general shape of this relationship represents a fair compromise between precision and expense, especially given the need for vessel time for other types of surveys conducted by the NEFSC. As noted by the National Research Council, substantial improvements in the precision of abundance measures for individual stocks (inhabiting a portion of the survey region) are necessary, and can be accommodated with modest directed increases in sampling intensity.[10]

The precision of transect surveys (e.g. hydroacoustic surveys for fish and line-transect sighting surveys for marine mammals) is determined by the number of miles of transect covered (proportion of the area occupied by the species that
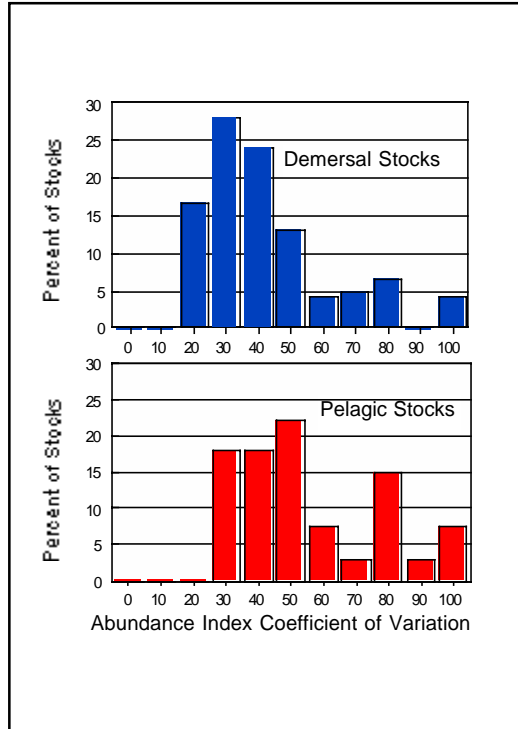

Figure 6.

Precision of Northeast trawl surveys for demersal and pelagic stocks.
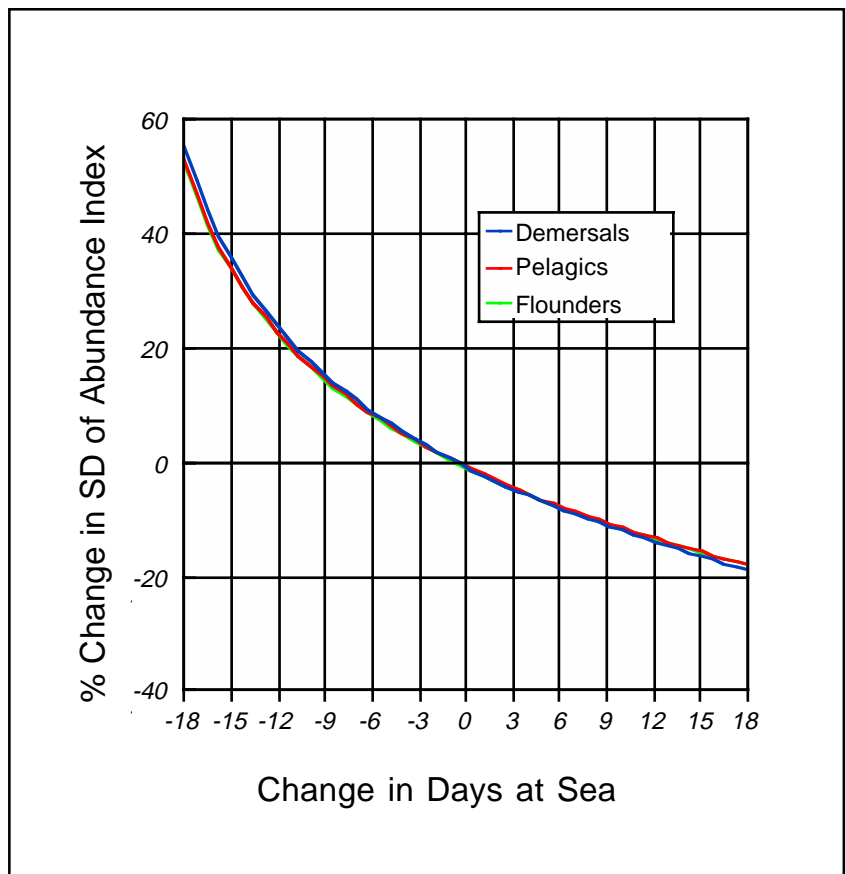

Figure 7. Change in precision of autumn bottom trawl surveys for Northeast pelagic and demersal fish and flounders with change in survey length from the standard 48-day duration (lines are almost identical and thus overlay one another).

is sampled, and the spacing between these transects in addition to the inherent variability of the species abundance (Fig. 8). The relationship between precision and spacing of such transects is approximately linear, but it differs among species and stocks owing to aggregation patterns, oceanographic features, and land masses. For hydroacoustic surveys conducted in the Bering Sea, Gulf of Alaska, and along the West Coast, the relationship between inter-transect distance and precision of survey abundance estimates (relative estimation error) has been estimated.[11] For pollock at Bogoslof, the relationship is rather steep, indicating that at critical spacing distances greater than about 15 n miles, the precision of the estimates degrades quickly. This is due to the extremely "patchy" distribution of pollock in this area. Conversely, pollock on the NW and SE shelf are more uniformly distributed, and the relationship between error and transect spacing is less steep. For all these stocks, the current spacing width and associated estimation errors are circled. The current sampling effort produces relatively precise abundance measures (error <15%).
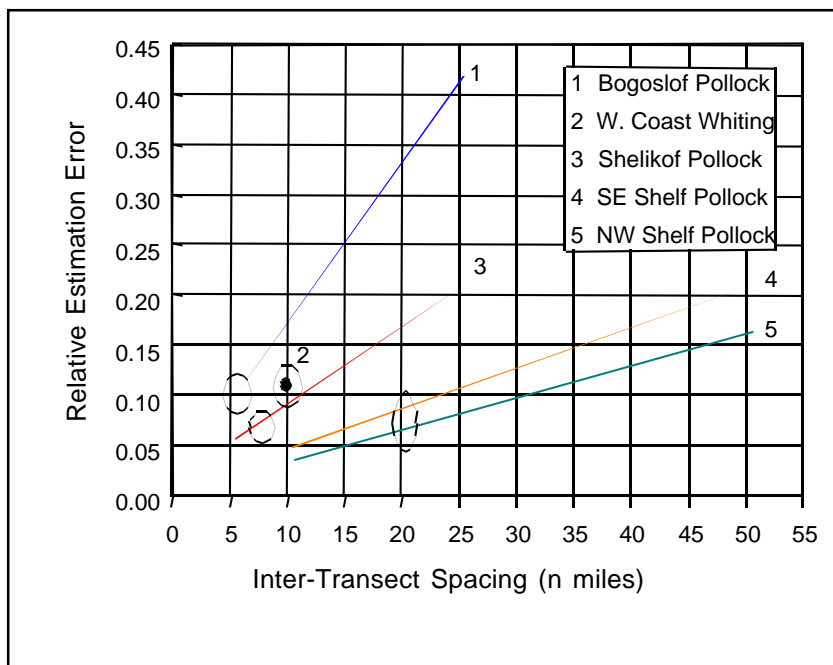
How often should resources be surveyed? Survey frequency is primarily related to how quickly populations change relative to environmental conditions and harvesting rates. Thus, since harbor porpoise populations change at a rate of about 4% per year, a two-year interval between surveys is appropriate, particularly since the CV of the population estimate exceeds their annual rate of change. For plankton communities, multiple surveys within years are important, considering their short life cycle. Most fishery species require annual resource assessment (finfish and shellfish), since recruitment rates may vary by an order of magnitude from year-to-year, and harvests rates may be high. One such case is North Atlantic sea scallop, where very high harvest rates have rendered it a "recruitment fishery," heavily dependent on small recruiting animals.

Examples of How Survey Duration Is Set

Precision requirements set the criteria for sampling intensity, and life history characteristics such as length of life cycles, distribution patterns, and habitat preferences all influence sample size needed to meet precision criteria. These principles are all used to develop sampling strategies for stock assessments of species or species groups covered in FMPs. Some examples of how the duration of specific missions were determined are provided below. Appendix C lists all missions needed to meet NOAA Fisheries' data requirements, including mission durations. The missions highlighted in these examples are cross referenced to that table.

A Bering Sea Example

The North Pacific Regional Fisheries Management Council (Council) developed a Fisheries Management Plan for Bering Sea Groundfish. Alaska pollock (pollock) is a major species in the groundfish complex in the eastern Bering Sea (EBS). The stock assessment model, used by the Alaska Fisheries Science Center (AFSC), to provide the Council with an array of harvest options for pollock requires a fisheries independent index of stock abundance. The AFSC has developed a research hydroacoustic system that provides an efficient (in both time and space) method of gathering the information on the abundance and composition of exploitable pollock stock. The AFSC's researchers working with the Council's Bering Sea Groundfish Team have determined that a level of precision of 15% for the estimate will provide the

Figure 8. Precision of hydroacoustic surveys relative to distance between line transects. The current spacing width and associated estimation errors are circled.

Apart from the issue of precision, population abundance indices may be biased if portions of the geographic distribution of a stock are not sampled, or are sampled differentially over time. Such may be the case for Pacific whiting, where the availability of DAS limits the ability to sample this unit stock in Canadian waters.

Council with a reasonable level of certainty that the information will lead to a correct management decision. The EBS pollock in the US EEZ are distributed over a 100,000 square n mile area. To obtain this level of precision, the survey trackline legs need to be spaced at 20 n mile intervals, which results in a total trackline length of 5,500 n miles. Traversing the trackline at 11 knots requires 30 days-at-sea (DAS). However, 2 to 3 midwater trawl tows are undertaken per day to collect biological samples for determining growth rates and age distribution, also needed by the model, and to verify species identification of acoustic targets. Trawling adds 10 DAS to the stock assessment cruise. An additional 10-12 DAS are required for two round trip transits to the grounds from Dutch Harbor (7 DAS), calibration of acoustic system (2 DAS), and weather days (2 DAS). An additional 19 DAS are added to the cruise to extend the survey into northwestern Bering Sea within Russia's EEZ. All these total 70 DAS for a cruise to survey the full range of the eastern Bering Sea pollock stock (Appendix C; Survey 4.2).

A California Current Example

The Pacific Fishery Management Council developed a Fisheries Management Plan for West Coast Groundfish that includes management of many species of rockfishes (*Sebastes* spp.). The stock assessments for rockfishes employ a combination of fishery-dependent and fishery-independent information. The strength of incoming (recruiting) age groups in each year has been a major source of uncertainty in setting optimal harvest levels. The Southwest Fisheries Science Center has developed a juvenile rockfish survey off the Central California coast that is able to measure recruitment strength three to seven years (depending on species) before those recruits enter the fishable resource, providing management with an extraordinarily useful forecasting and management tool. The juvenile rockfishes, at an age of a few months, are sampled just as they make the transition from open water to bottom habitats where they become unavailable to existing sampling methods. This happens in late spring each year, with some variability as to the exact time. Initial pilot surveys determined that three eight-day sweeps (a sweep consists of eight nightly trawl transects at standard locations) of the regions conducted be-

tween mid-May and mid-June assure that the transition event will be sampled. Experience has also shown that survey time can be lost to bad weather, so three "weather days" are added to each sweep, for a total of 33 days of survey time. The ship requires four days to transit to and from San Diego, and requires one in-port day during the survey, bringing the total to 38 DAS to accomplish the survey Appendix C; Survey 6.12). Any unused weather days are used for opportunistic and process-oriented studies to improve survey performance and understanding of oceanographic influences.
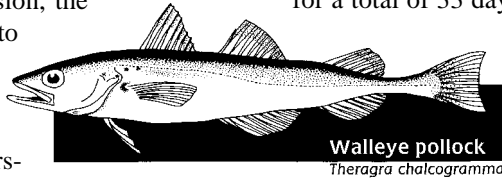
An Eastern Tropical Pacific Example

The International Dolphin Conservation Program Act (IDCPA) includes a mandate that NOAA Fisheries conduct assessments of dolphin populations that are chased and captured in the purse seine fishery for yellowfin tuna to determine whether the activities of this fishery have an adverse impact on dolphin populations. If an adverse impact is detected, the definition of "Dolphin Safe" tuna will remain unchanged. Assessments of dolphin stocks are conducted using well-established line transect techniques. Based on extensive experience surveys on these populations, the expected level of precision in the estimate generated from a specific amount of survey effort can be determined. Thus, sea days for the surveys are determined by deciding on an acceptable level of precision in our results. For the upcoming cruise, the target level of precision is a coefficient of variation on the population estimate of 15% or less. Three vessels will cover approximately 51,500 nautical miles with the search effort totalling approximately 30,000 n miles. The ships will conduct about 120 survey days each, steaming at about 10 knots during daylight hours (12 hrs/day). A significant amount of each daylight period will be spent approaching aggregations of dolphins for positive identification and estimation of group size. Based on previous experience this survey strategy will result in encounter rates that should be adequate to meet the precision requirements of this survey (cv=15%). The survey will be conducted from three vessels for a total of 360 DAS for one year, and for 2 years following that using 2 vessels at 150 DAS each (Appendix C, Survey 6.19 & 6.27).

A Pacific Oceania Example

The blue shark population biology and bycatch assessment in the Pacific Oceania ecosystem is conducted annually over two cruises (Appendix C, Survey 5.5). To collect enough specimens to monitor sex and size composition, state of maturity, and fecundity of blue sharks, at least 22 longline sets must be made. One longline set can be made per day (or night), so this requires 22 DAS. Transit to and from the sampling area at the subtropical front requires six DAS. A slack of two DAS is allowed to accommodate gear breakdowns and severe weather and sea conditions, bringing the duration of this cruise to 30 DAS.

The second cruise is designed to assess oceanographic conditions and concurrent information about blue shark movements in the water column. To provide sufficient data, at least five transects with 12 stations per transect are required. A single transect can be completed in one DAS, so a total of five DAS are required for the oceanographic sampling. An additional six to seven DAS are needed to capture and track movements of blue sharks in the water column. Adding three DAS to cover transit time and to accommodate unexpected delays brings the total to 15 DAS. Together, these surveys total to a 45 DAS to meet the data requirements of the mission.

A Gulf of Mexico Example

Choices for survey durations are governed by two principles - they should be synoptic (i.e. a snapshot in time), and should cover the full range of each stock targeted. Synoptic is a relative term in stock assessment in the Gulf of Mexico. Marine mammal surveys conducted over a 2-to-3 yr period might be considered synoptic due to the longevity of these species. Conversely, phytoplankton surveys must be conducted many times per year, with special consideration to the reproductive season. The SEAMAP summer groundfish survey is conducted annually in the Gulf of Mexico (Appendix C; Survey 2.2). To meet the established precision criteria, a total of 250 trawls must be made. Eight trawls can be made on the average work day, so the full survey requires 32 days. Two days are built into the schedule as weather days, and transit time to and from port add another 3 days bringing the total DAS requirement for this survey to 37.

A South Atlantic Example

The South Atlantic shark longline survey takes place annually over summer months (Appendix C, survey number 3.2) Since a total of 70 longline stations must be sampled to meet the precision criteria, and 6 stations can be sampled per day, a total of 12 DAS are needed to complete this mission. Transit time to and from the port and from station to station totals 15 DAS. Added to this are 3 days to account for bad weather or unanticipated delays, which brings the total requirement to accomplish this mission to 30 DAS.

A Northwest Atlantic Example

Groundfish species in New England waters are currently managed under an FMP developed by the New England Fishery Management Council. The plan specifies management measures for 13 species comprising 22 stocks of demersal fishes such as cod, haddock and flounders. Assessments for most stocks in the complex provide estimates of current fishing mortality rate (F) and spawning stock biomass (SSB) with moderately narrow confidence intervals. Assessment results and advice to the Council is provided through the Northeast Stock Assessment Workshop (SAW) peer review process. The advice is usually given as estimates of the current values of F and SSB and their 80% confidence interval (e.g., for Georges Bank haddock F=0.11, 80% CI=0.098 to 0.12; SSB=40.5 thousand mt, 80% CI=34.2 to 48.1 thousand mt). The assessments allow explicit probability statements about the current condition of the resource, relative to plan guidelines for F and SSB (e.g., in 1997 there was a 0% probability that the SSB of Georges Bank haddock was > the 80,000 mt minimum biomass threshold required under the FMP).

Data used in groundfish assessments include commercial landings, discards (where appropriate), biological sampling of the catch for age, weights, etc., and fishery-independent estimates of relative abundance. The centerpiece of New England groundfish assessments is the 35+ year time series of bottom trawl survey indices (Appendix C; Survey 1.1). Spring and autumn time series exist for the USA, and these data are augmented by Canadian trawl survey data for Georges Bank resources. A total area of 250,000 km² is surveyed with bottom trawls. A typical survey will make 350 half-hour trawl tows in the region, with the distribution of these samples allocated randomly within regional depth strata. The choice of

the number of sea days to allocate to this survey (currently 48) is based on the logistics of staging a survey over such an extensive area, combined with the appropriate precision required to give effective assessment advice for about 50 important resource stocks. Precision levels of assessments (haddock -- 11% CI for fishing mortality rate, 17% for SSB) have been appropriate for making informed and critical management decisions by the Council and NOAA Fisheries. Precision of assessments varies substantially by stock, with the importance of the stock to the fisheries and likelihood of the resource being overfished being the primary criteria used in establishing precision requirements.

A Southern Ocean Example

Annual trawl surveys will be conducted along the Antarctic Peninsula to determine finfish biomass and around South Georgia Island to determine crab biomass. Since the first finfish survey along the Peninsula was conducted just last year, there are limited data to help determine what level of precision might be expected from various levels of sampling effort. Experience has proven that four stations per day can be surveyed. Trawling is limited to daylight due to behavioral patterns of the fish. To meet precision requirements, 80 stations each will be sampled along the Peninsula and the South Georgia sites. At four stations per day, this accounts for 40 DAS. Transit to and from the two study sites will add 14 DAS to this. Six days will be spent in the port (2 days before, 2 between and 2 after the surveys. This totals to 60 DAS to accomplish this mission (Appendix C; Survey 7.3.

Data Priorities

Because fiscal resources for fisheries management are not unlimited, a hierarchical system of priorities must be set to ensure that the most important data needs are met. First priority must go to endangered or threatened species. For example, all marine mammals are protected, but special emphasis is given to the endangered species among them. Among fish species, those that are overfished are also given high priority because adequate stock assessments and monitoring programs are essential to track the success of rebuilding programs on these stocks.

Another consideration when setting priorities is the value of the stock or species to the U.S. economy. However, the ecological importance of a species is also considered. Surveys may be conducted on a species of little economic value, but which is an important forage fish for, or predator on other stocks, or is a bycatch species.

Summary

The process for determining sampling strategies is clearly complex, driven by a combination of ecology and logistics. Fiscal constraints limit NOAA Fisheries' ability to conduct stock assessments on all managed species, requiring difficult decisions to be made on how ship-time is allocated among competing data needs. Currently, status relative to overfishing is known for only 38% of the 727 stocks covered by FMPs (Table 1). This means that for the remaining 62% of FMP species, insufficient data exist to conduct a stock assessment.[2]

Assessment Status of Fishery Mangement Plan Stocks			
Large Marine Ecosystem	# FMP Stocks	% Assessed	% Unknown
Gulf of Alaska / Bering Sea	106	60	40
California Current	109	32	68
Pacific Oceania	64	80	20
Southern Ocean	N/A	N/A	N/A
Gulf of Mexico / Caribbean	248	6	94
South Atlantic	84	23	77
North Atlantic	46	74	26
Atlantic-wide *	70	87	13
Total FMP Stocks	727	38	62

* This category includes shared stocks between the No. Atlantic/So. Atlantic/Gulf of Mexico and the Highly Migratory Species

VESSEL ASSETS AND ALTERNATIVE APPROACHES

In this section, alternative research platforms and service providers are introduced and examined with the objective of meeting NOAA Fisheries' data requirements at the lowest cost. Four general classes of assets are reviewed here: 1) dedicated FRVs, 2) UNOLS oceanographic vessels, 3) fishing industry fleet, and 4) advanced technology.

Fisheries Research Vessels

Special Requirements of FRVs

Modern FRVs are characterized by acoustic quieting, program versatility, modern specialized

Table 1.

Percent of species/stocks covered by Fishery Management Plans with known status relative to overfishing.

science laboratories and scientific equipment, seakindliness, and stationkeeping through dynamic positioning, with adequate berths for scientists. Such vessels support resource surveys through trawling, longlining, hydroacoustics, visual observations, and simultaneous fisheries, oceanographic, and environmental research. They have accommodations for up to 19 scientists, endurance up to 40 days, and a cruising speed of 14 knots.

New technologies for fisheries research that improve quantification and identification of species are important. Equally important is the ability to integrate new sampling, measurement and data acquisition systems into resource surveys and process-oriented research programs. Although new technology may reduce the number of trawl/dredge tows that are required for some species, the capability to conduct traditional resource surveys for many species, and the ability to collect fish and shellfish will continue as a requirement. In addition, to secure "ground truth" for remote sensing technologies (for example, hydroacoustic assessments) no foreseeable substitute exists for specimen-dependent research (for example, maturity, fecundity, feeding interrelationships, age and growth studies, and pathology).

... new FRVs will be quiet, versatile, and state-of-the-art ...

In addition to the capabilities of the existent ships, the new FRVs must accommodate three important new technologies that improve the precision of fisheries assessments and enhance process-oriented research. These new technologies are:

1) Research Hydroacoustics: Already in use for estimating semi-pelagic fish stocks, this technology continues to develop rapidly. Improvements in transducers and signal processing combined with use of multiple frequencies are leading toward higher target resolution and discrimination

2) Video: Continuous developments in towed camera arrays will improve real-time assessments of benthic epifauna; and

3) ROVs and AOVs (Remote- and Autonomous-Operated Vehicles): These vehicles, equipped with low light level cameras, can augment and extend population assessments to areas where sampling is not possible by traditional techniques (reefs, rock areas).

To support the integration of these new technologies into NOAA Fisheries operations and improve the current fleet capabilities, the FRVs must include a number of special capabilities in their design. These include:

1) Acoustic quieting to meet the Council for the Exploration of the Seas (ICES) standards for hydroacoustic surveys. This is the most important special requirement of new FRVs. Acoustically quiet vessels will reduce the noise at frequencies known to disturb surveyed fish (less than about 1 kHz), thereby increasing echo detection and reducing avoidance reactions of fish or marine mammals. To reduce noise at the higher frequencies used to assess fish (usually 38 and 120 kHz), extendible transducers, e.g., mounted on a centerboard, should be used.

2) Versatility of deck equipment, deck space, laboratory space, to study the relationships among managed species, the food web, and the environment upon which they depend in near real-time. This allows researchers to investigate multiple aspects of a problem aboard a single vessel, to conduct flexible missions, and to adapt to new programmatic demands that will likely emerge during the ships' service life.

3) Modern science laboratories and scientific equipment. In addition to processing (wet) laboratories, the new vessels require laboratories with stable electrical power for supporting sensitive analytical instrumentation.

4) A modern computer system for integrating meteorological, oceanographic, and hydroacoustic, and positional data acquired through ship's sensors.

5) Seakindliness (a smooth and stable ride) is essential for investigators working in on-board laboratories. Violent motions can degrade and even preclude operation of many scientific instruments.

6) Stationkeeping through thrusters, integrated with a dynamic (computer-controlled) positioning system, to remain on-station for prolonged sampling periods and to follow precise track lines in a variety of sea conditions are needed.

7) Adequate number of berths for scientific complement. *In situ* and laboratory experimentation require a diverse team of scientists and support technicians. Depending on the program, the scientific complement will require up to 19 staff.

FRV Safety Requirements

In addition to meeting mission requirements, new FRVs should meet modern safety requirements, such as ABS classification, Coast Guard Subchapter U regulations, and SOLAS lifeboat regulations. Ship expected to use foreign ports should meet all applicable SOLAS regulations.

The safety regulations in the USCG Rules, *46 CFR Subchapter U, Oceanographic Research Vessels*, require an inspected operator to meet a one-compartment flooding damage stability criteria, when carrying a scientific party. Meeting this regulation requires a watertight bulkhead, remote controlled sliding watertight doors, an alarm system, programmed, automated alarm points to maintain the ACCU ABS unattended engine room status, and an approved fire and smoke detection system. Production of a trim and stability booklet is needed to demonstrate to the regulatory bodies (ABS and USCG) that the ship is safe which will enable third party certification from ABS, USCG and others.

UNOLS Research Vessels

UNOLS vessels are designed for conducting multidisciplinary oceanographic research for the academic community. They cannot handle commercial-sized trawls (e.g., they lack stern trawl ramps, multiple trawling winches, and catch handling equipment) and pelagic longlines, traps, purse seines, and active and passive hydroacoustic gear, and thus do not meet the primary requirements of a FRV. Further, the UNOLS ships are not built to meet the ICES Standard of quieting required for hydroacoustic surveys. However fisheries oceanography, some visual observations, egg and larvae surveys, and environmental research can be carried out on UNOLS vessels. Collaborative fisheries research programs between NOAA Fisheries and academic scientists, such as GLOBEC, currently use UNOLS vessels and will continue to do so.

UNOLS ships are scheduled annually, which has made use of these ships difficult. Although there appears to be some limited time available, requirements for recurrent vessel use in the same geographic area at prescribed times would necessitate modification of UNOLS scheduling procedures and commitment of blocks of time to NOAA Fisheries programs. If UNOLS vessels were built with fisheries survey capabilities and could be operated at a reasonable cost, they could be increasingly used in the NOAA Fisheries stock assessment mission.

Fishing Industry Fleet

The commercial fishing fleet is a valuable resource to NOAA, and contributes significantly to the pool of data used to manage fisheries. Many missions are ideally suited for fishing vessels, such as gear test studies, bycatch studies, and exploratory fishing. Chartered fishing vessels are also appropriate platforms for standardized stock abundance surveys that use gears less sensitive to changes in vessels, such as traps, purse seines, and longlines. Vans containing specialized acoustic or laboratory equipment or dormitory space can sometimes be placed aboard these vessels to temporarily enhance their capabilities.

Challenges to the use of commercial fishing vessels include availability of suitable vessels, and continuity of availability. Standardized sampling often requires a relatively rigid sampling schedule to maintain data continuity. When a sampling season coincides with a commercial fishing season, the few charter vessels willing to shift their focus from fishing to data collection will do so only at a prohibitive cost .

Advanced Technology and Data Collection

Many programs within NOAA Fisheries already use, or are actively developing, applications of advanced technology for marine research and monitoring. The technologies most relevant to planning for future vessel services generally involve sensing marine organisms without capture, or broadscale characterization of the marine environment. The two major classes of technology are those used aboard vessels (e.g., acoustic or laser line technologies) and remote sensing (e.g., passive satellite or aircraft sensors, and lidar). Technologies used aboard vessels often demand special vessel requirements. In some special cases, remote sensing technologies may replace functions previously requiring vessels, but more often their main value is to augment data collected from vessel surveys with data that are unique or are taken at a larger scale.

Acoustics

There are five main types of applications of acoustics either underway or under development in NMFS (Table 2). First, acoustics are presently

Science Center	Survey Types
	Abundance Surveys
AFSC	Pacific whiting since 1974, wallye pollock since 1979
AFSC	Fixed-array acoustics (SOSUS) for marine mammals
NEFSC	Small pelagics (herring, mackerel, butterfish, squids)
SEFSC	Small pelagics, reef fish, sharks
	Locating Aggregations for Specialized Research
SEFSC	Menhaden spawning, grouper spawning
SWFSC	Food chain dynamics
	Gear Performance
NEFSC, SEFSC	Specialized cruises for activity
AFSC	Routine gear mensuration
AFSC	Vessel avoidance (with acoustics survey)
	Telemetry
NEFSC, SWFSC	Sharks
SEFSC	Sea turtles
SWFSC	Pacific salmon, habitat utilization
	Bottom Characterization
AFSC	Quantitative description of sea floor
SEFSC	EFH, potential marine reserves

Table 2.

NOAA Fisheries projects that use acoustic technology by survey type and science center.

used in developing indices of stock abundance for mid-water, single-species aggregations of fish. Use of this method is currently limited by the inability to distinguish among species, inability to distinguish targets close to the bottom, and by the substandard quieting of existing research vessels. Choices thus far have been to limit surveys to geographic areas dominated by single species, to utilize only biomass information without species identification (with limited management applicability), to begin research to identify either individual targets or schools from acoustic signals, or to deploy trawls upon contact with substantial acoustic targets. Design features of the new FRVs (acoustically quiet, and equipped with a centerboard to allow transducers to operate below the interference of the bubble sweep) will improve the efficiency of hydroacoustic surveys.

The second application for acoustics technology is locating aggregations for specialized re-

search. Examples are the research on distribution, abundance, foraging, behavior and aggregation of fish and zooplankton, conducted by the SWFC. Another example is the work by the SEFC on finding and mapping spawning aggregations of Atlantic menhaden, and assessment of spatial distribution and abundance of fishes in general. The National Marine Mammal Lab is experimenting with SOSUS (SOund SUrveillance System), a fixed array of acoustic receivers that can detect marine mammals over wide areas of the ocean. The technology is very promising for many applications, but is unlikely to provide, by itself, the quantitative abundance data needed. Current plans focus on integrating SOSUS data with data from visual shipboard surveys. Yet another example is the work conducted by the NEFSC using hydrophones to monitor harbor porpoise behavior in response to sink gillnets.

The third application of acoustics is monitoring gear performance. The NEFSC and AFSC evaluate bottom and midwater trawl performance by measuring wingspread, doorspread, headrope height-depth, water temperature and indication of catch to help standardize trawl surveys. The AFSC also conducts vessel avoidance studies to quantify the response of fish to vessels conducting trawl and hydroacoustic surveys.

The fourth application of acoustics is the use of acoustic tags to monitor movement of animals. Tags are affixed to study animals and their movement is monitored by research vessels. Both the NEFC and SWFC are conducting work on sharks using acoustic tags. The SWFSC also uses tags to monitor salmon.

Finally, with the recent emphasis on EFH definition, quantification of bottom habitat using acoustic techniques has become an active area of research. Recent advances in digital signal processing have enabled quantitative descriptions of sea floor using conventional echosounders. This method has low per-unit sample costs, enabling broad areal coverage.

Satellite Remote Sensing
Satellite remote sensing can be a powerful tool in fisheries oceanography research, fisheries management, marine protected species research and management. There are four types of satellite remote sensing applications common within NOAA Fisheries: 1) broad scale environmental characterization; 2) location of special environ-

mental features; 3) telemetry using satellite tags; and 4) real-time survey design (Table 3). Sensors now exist to provide data on sea surface temperature, ocean color, wind speed and direction, sea surface height, wave height, and ice cover, and to track vessels and tagged animals. Satellite remote sensing is particularly useful for monitoring changing oceanographic conditions, since it can provide high resolution data synoptically, with frequent coverage.

Significant progress has been made in the utilization of satellite data in recent decades. This has occurred primarily because of increases in availability and improvements in access to some data, the development of user-friendly data processing software, and increasing awareness of the utility of the data for fisheries research and management. This trend is likely to continue as new sensors become available.

NOAA Fisheries uses data from many sensors, but four sensors/data are particularly important. Advanced Very High Resolution Radiometer (AVHRR) sea surface temperature (SST) data are among the most commonly used remote sensing data. The data indicate oceanic features such as fronts, eddies or upwelling zones which can be used to predict fish distribution for a wide variety of research or operational applications.

With the launch of SeaWiFS in 1997, ocean color data became widely available to the fisheries and oceanographic research communities. Ocean color can be used to look at large-scale patterns of primary productivity in the ocean. In the future, it may be used to detect harmful algal blooms. Synthetic Aperture Radar (SAR) data can be used to derive wind fields and identify upwelling and downwelling areas for oceanographic research, track red tides via surface density anomalies, and monitor sea ice coverage. In the future, SAR may be used for vessel tracking and to identify schools of pelagic fishes at the ocean surface. Two advantages of SAR are that it can penetrate through clouds and it can operate at night. The ARGOS satellite tracking system is used to track cetaceans and sea turtles and in vessel monitoring. In the future, ARGOS may be used to relay data from fish tags that are programmed to disengage from fish and float to the surface.

Satellite technology is extremely powerful in its ability to bring large scale synopticity to environmental observation, but severely constrained

Science Center	Application
All Regions	Enviromental Characterization (broad scale)
	Location of Oceanographic Features / Habitat
SEFSC	Dolphins / gear interactions, transport in SABRE, sea turtles in trawl fisheries
	Satellite Tagging
NEFSC	Harbor porpoise, right whales habitat use (migration paths and closed areas)
SEFSC	Sea turtles (behavior, time-at-surface), ARGOS drifters for transport in SABRE
SWFSC	Large pelagics
AFSC	Marine mammal telemetry, Pacific salmon telemetry
	Assistance in Survey Design (limited)
NEFSC	Cetaceans
AFSC	Sea ice / pinniped
SWFSC	Research cruise design

Table 3.

Applications of satellite technology by fisheries science center.

by its inability to see below the ocean surface. Satellite remote sensing, therefore, cannot replace *in situ* measurements. Satellite remote sensing is restricted, in many cases, to cloud-free areas during daylight hours. Ships, data buoys, and fixed and floating instrument arrays are all necessary to make observations beneath the surface and to calibrate and validate measurements made from space.

Lidar

Lidar (Light Detection and Ranging) is a particularly attractive technology due to its ability to penetrate the water column, and due to its operation from aircraft, potentially covering an area perhaps 20 times faster than a vessel could. However, trial applications have often been limited by the energy required for meaningful penetration of the water column. A very high energy beam would be required to penetrate turbid waters. Thus practical application is limited to near-surface phenomena in many cases, and problems of target identification, analogous to the problems in acoustics, remain. Currently, the southwest region is most active in lidar research, with realistic potential identified for sardine and squid surveys. It seems most likely that lidar will have applicability in surveys of only a few species.

Laser line

The recent release of laser line technology is generating considerable interest in NOAA Fish-

Figure 9.

Allocation of days-at-sea by matching research mission to the appropriate platform.

Meeting the Data Requirements

The next step in this process is to integrate the information described in the previous sections into the *Plan*. Data requirements were reviewed by a team of stock assessment and resource management experts and the results are presented here. Options to meet vessel needs were identified and studied and the outcome of that work is also presented. Finally, data requirements are translated into ship-time requirements and the strategy for meeting the requirements is presented.

Data Acquisition Planning

A team of stock assessment experts and ship operations specialists representing each of the ecosystems within the US EEZ and cross-cutting the Sustainable Fisheries, Protected Species, Habitat Conservation, and Science and Technology Offices of NOAA Fisheries, participated in a workshop to synthesize this information into a draft Data Acquisition Plan. The workshop was the culmination of many years' examination of existing needs, new opportunities generated by legislative changes, potential technological advances, and shifts in resource uses and management focus. Using all this information as input, the Plan was constructed through an iterative process, balancing data needs, priorities, logistics, and fiscal constraints to arrive at a solution that optimized the quantity and quality of information collected.

The first step in the iterative process was to evaluate the current data acquisition program to determine if shifts in priorities are appropriate and to identify data deficiencies. Next, data needs based on MSFCMA, MMPA and ESA legislation were quantified. Combining these produced a comprehensive list of data needs which was partitioned into missions. Survey durations and frequencies were assigned to the mission list. Allocation of missions among vessel types was accomplished by matching the requirements of the mission to the most appropriate vessel type within the pool of available vessels (Fig. 9). Generally, multipurpose missions or those involving hydroacoustics or long-term standardization were assigned to FRVs, while single-purpose missions were typically assigned to charter vessels. Next, logistic constraints such as spatial and temporal conflicts among missions and vessel types and fiscal constraints were evaluated. Through this iterative process, data needs were translated into DAS, and then into mission plans (Appendix C).

eries. Initial applications will probably focus on bottom habitat characterization. Laser line technology may be extendable to many of the applications currently considered for acoustics, with the added advantage of superior imaging capability. However, problems with species identification parallel to those described under acoustics have yet to be addressed. Laser line technology may be less demanding on vessel characteristics than acoustic technology.

In summary, the array of high technology techniques becoming available have considerable application for some types of research problems. Investing in advancing these technologies through partnerships with other government agencies, universities and private industry is part of the *Plan*. These technologies provide data that greatly enhance standardized stock assessment surveys required for fishery management decisions. However, they are not likely to replace vessel-based sampling for several decades, if ever.

In FY98, NOAA Fisheries' scientists will use a total of 3104 DAS, with FRV DAS on the 8 2/3 ships in the NOAA fleet accounting for 61% of the total. Results of the planning workshop indicate that a minimum of 6000 DAS (nearly double the present effort) are required to continue current research and monitoring, to address the increased information requirements of the MSFCMA, MMPA and ESA, and to provide the scientific foundation for implementing new approaches to fisheries management (Table 4; Fig. 10). This expansion of DAS would considerably improve stock assessment capabilities by allowing stock assessment surveys that are inadequate in scope to be augmented and initiation of new assessments on managed stocks not now addressed (Appendix D). Resources would also be dedicated to ecosystem process and life history studies needed to predict future yields and set fishing quotas.

Options Considered

With the data requirements now identified, a strategy was developed to meet them. One of the challenges in this process is that NOAA Fisheries' fleet of research vessels have reached or exceeded their expected service life. For several years, options have been studied to mitigate for their eventual attrition from the fleet. The options have been analyzed by an interdisciplinary team of scientists, acquisition specialists, design engineers and consultants from NOAA, other federal agencies and the private sector. The options include:

• Convert and purchase or lease existing ships to serve as research vessels

• Increase the amount of research conducted on chartered vessels

• Implement a major repair program to prolong the service life of the existing fleet

• Increase the role of advanced technology in data collection

• Construct new FRVs

Convert Existing Ships

NOAA evaluated existing ships as an alternative to new construction through two studies. First, NOAA did a market survey in 1996 in search of suitable candidates using the UNOLS ship lists maintained on the Internet by the University of

Ship Type	DAS	Area	Ship Years
Quiet FRV	414	Northwest Atlantic	1.53
Quiet FRV	336	Gulf of Mexico/ Caribbean	1.24
Quiet FRV	106	South Atlantic Coast	.039
Quiet FRV	565	Gulf of Alaska/Bering Sea	2.02
Quiet FRV	400	Pacific Oceania	1.48
Quiet FRV	695	California Current	2.57
Subtotal	**2,516**		9.32
Charter FRV	120	Southern Ocean	
Subtotal	**120**		
Quiet RV	90	Northwest Atlantic	
Quiet RV	230	California Current	
Subtotal	**320**		
Charter Oceanographic RV	88	Nothwest Atlantic	
Charter Oceanographic RV	15	Gufl of Mexico/Caribbean	
Charter Oceanographic RV	50	South Atlantic Coast	
Charter Oceanographic RV	55	Gulf of Alaska/Bering Sea	
Charter Oceanographic RV	234	California Current	
Charter Oceanographic RV	60	Southern Ocean	
Subtotal	**502**		
Charter RV	125	Pacific Oceania	
Charter RV	60	Southern Ocean	
Subtotal	**185**		
Charter State RV	40	Gulf of Mexico/Caribbean	
Charter State RV	120	South Atlantic Coast	
Subtotal	**160**		
Charter	134	Northwest Atlantic	
Charter	245	Gulf of Mexico/Caribbean	
Charter	70	South Atlantic Coast	
Charter	834	Gulf of Alaska/Bering Sea	
Charter	230	Pacific Oceania	
Charter	689	California Current	
Subtotal	**2,202**		
Quiet FRV Subtotal	**2,516**	**42%**	
Other Subtotal	**3,489**	**58%**	
Grand Total	**6,005**	**100%**	

Delaware, and through direct contact with the Maritime Administration (MARAD) and Military Sealift Command (MSC). NOAA also contracted with Naval architects on each coast to determine the availability of private sector vessels. Results showed that no suitable ships existed that met the principal characteristics (i.e. size, horsepower, subdivision, space for accommodations and labs, arrangements to allow effective quieting, life expectancy, etc.) which we could economically convert to meet the mission requirements.

Table 4.

Survey of days-at-sea by vessel and ecosystem type based on planning workshop results.
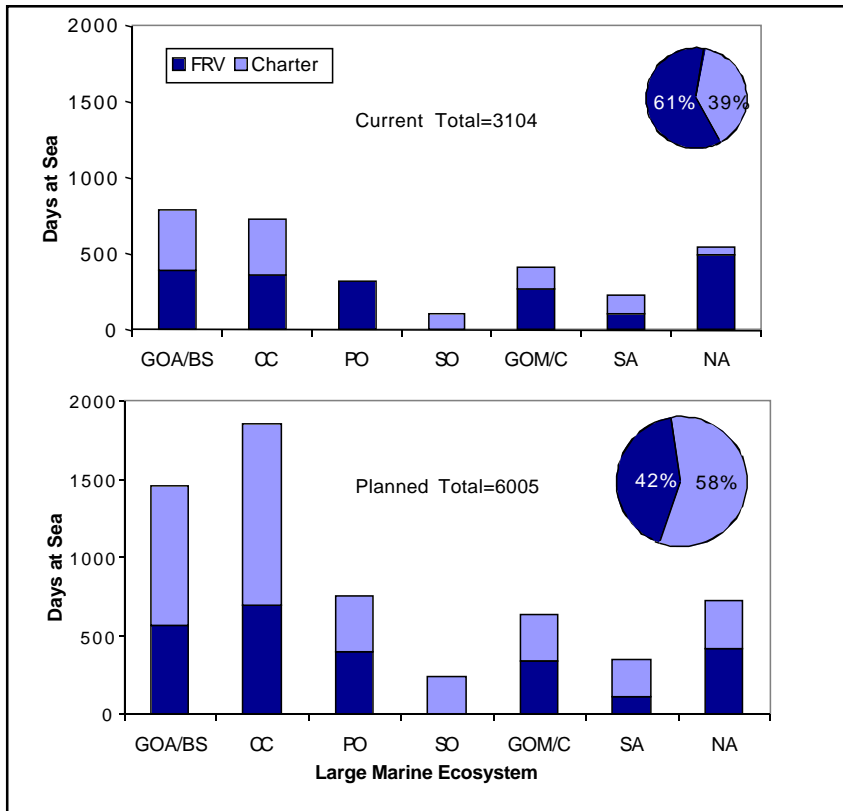
Figure 10.

Current FRV and charter days-at-sea (upper) versus levels needed to meet data requirements based on study results. Large marine ecosystems are Gulf of Alaska/ Bering Sea (GOS/BS), California Current (CC), Pacific Oceania (PO), Southern Ocean (SO), Gulf of Mexico/Caribbean (GOM/C), South Atlantic (SA), and North Atlantic (NA).

After a review of the ship acquisition process, OMB asked for another market survey, which was independently conducted by MSC. Vessel requirements were released electronically to over 90 addressees, posted to the MSC home page on the Internet and posted as a "Sources-Sought" announcement in the Commerce Business Daily (CBD). Vessels that met the critical requirements, but failed to meet requirements not identified as critical were considered capable of conversion and their owners were encouraged to respond. Results of this study were the same as for the previous one. No vessels were found in the U.S. flag fleet that were suitable for conversion to meet NOAA missions.[12] Based on these investigations, it became clear that conversion of existing ships could not exclusively meet the mission requirements.

Increase Use of Charters

NOAA Fisheries has steadily increased the use of vessel charters to the point that they represent about 40% of the total DAS in FY98. Use of charters will continue to increase in response to burgeoning information requirements and to the retirement of vessels in the NOAA fleet. Perhaps the factors that limit the use of charters most are the types of vessels available for charter and consistency in availability. Some missions simply must be conducted from an FRV with long-term availability. NOAA Fisheries will continue to work closely with the academic and fishing industry fleets to use them for suitable missions. In addition to that, FRVs that can be used to supplement the work of NOAA's core fleet of vessels are needed. UNOLS currently does not have fully capable FRVs in their fleet. However, plans are underway to modernize the academic fleet and this represents an opportunity to collaborate with them to meet NOAA Fisheries' vessel needs. UNOLS and NOAA Fisheries representatives have a healthy working relationship and collaboration is being actively pursued.

Implement a Major Repair Program

As the fleet has aged, NOAA has worked diligently to conduct major repairs, and some upgrades, to extend the life of its FRVs until replacement vessels can be acquired and calibrated. Nevertheless, these vessels have already served longer than their peers in other countries, and must be replaced very soon. It is not technically or economically feasible to repair them indefinitely; eventually a point of diminishing returns is reached. Moreover, none can be modified to meet the quietness standards, and all were designed for other missions, primarily exploratory fishing. They have been good ships and have served well, but they are obsolete and in deteriorating condition. Repairs will continue to be made to ensure the existing vessels can continue to serve safely and effectively until replacement vessels come on line and are calibrated.

Advanced Technology

The advanced technologies that can be used to acquire data were discussed earlier. None are likely to replace FRVs for several decades to come. However, several can increase the amount of data obtained by FRVs (e.g., acoustics) or can augment the use of FRVs (e.g., LIDAR). Some technolo-

gies can reduce the amount of FRV time needed by improving cruise planning. Over the last four decades, steady, but slow progress has been made, and several technologies are operational. There have been no striking breakthroughs, and none are on the immediate horizon. Nevertheless, scientists at each Fisheries Science Center, working with universities and technology corporations, are pursuing the latest developments and an advanced technology specialist is being recruited to coordinate these efforts in headquarters.

Construct New FRVs

Construction of new FRVs was explored as an approach to meeting at-sea data acquisition needs. Mission requirements from each of the science centers were obtained and a composite developed. Mission requirements were translated into a design through a design feasibility study.[13] The study validated the design requirements, offered analytical proof of concept and provided the first step in establishing a cost estimate for budget planning. This was done independent of both ownership and operating party decisions — the feasibility design has no features unique to any single operator. A rigorous external review of the ship requirements was conducted and concluded that "the FRVs as defined by the requirements statements will be outstanding vessels that should serve NMFS and the nation extremely well as the core of a dedicated fisheries fleet for their full projected lifetime...they are not overspecified."[14]

The FRV design maximizes utility of hydroacoustic technology by including measures to meet the International Council for Exploration of the Seas (ICES) noise standards for fisheries research vessels and positioning of acoustic transducers on a hull-penetrating centerboard to minimize interference of ship noise and bubble sweepdown with sensor performance.

The acquisition approach for the FRVs was studied using an economic model developed for NOAA by Program Management Associates, Inc. The model was designed to determine the most cost-effective method of acquiring ships, based on the input of 43 separate variables. The model results indicate that the life cycle cost of ownership is clearly less than that of leasing.[15] Sensitivity analysis was conducted for a variety of parameters including interest and discount rates, depreciation, lease term, etc. An independent verification and validation of the model by KPMG Peat Marwick Management Consultants confirmed that the model accurately compares the various acquisition options under consideration by NOAA (government owned and operated; government owned, contractor operated; contractor owned, government operated; contractor owned and operated). However, NOAA Fisheries maintains its position that either government or private sector ownership would be acceptable as long as the option selected is the most economical and does not compromise NOAA Fisheries' missions.

Requirements by Ecosystem

FRV ship time is needed in each of the ecosystems within the U.S. EEZ. Demands for quiet vessels in the Gulf of Alaska (GOA) and Bering Sea (BS) ecosystem to conduct hydroacoustic surveys with accompanying trawl ground truthing are growing. The MILLER FREEMAN and the JOHN N. COBB (age 48) currently serve this area. The MILLER FREEMAN will undergo a major repair period beginning in the fall of 1998, and will not return to duty until late spring of 1999, but the vessel is 31 yrs. old and is very near the end of its useful life.

In the California Current ecosystem, quiet FRVs would be used to conduct acoustic surveys for Pacific whiting. Deep-water trawl capabilities would enable the FRV to be used for new surveys needed at the shelf edge. Hydroacoustic surveys on California Current coastal pelagics such as anchovies, sardines and mackerels, would also be conducted from this ship. The multi-capable features of FRVs would allow much needed ecosystem-level investigations on juvenile salmon natural mortality in the ocean. A quiet ship would greatly enhance dolphin-tuna interaction studies in the ecosystem. Groundfish surveys, currently conducted triennially could be expanded to annual with the use of the FRV. The DAVID STARR JORDAN currently serves this ecosystem, but has only limited trawl capability. This 33 yr-old vessel is scheduled for a major repair period in 1999 which is expected to prolong its life by six years.

The shear magnitude of Pacific Oceania poses a challenge to stock assessment; the portion of the U.S. EEZ associated with Hawaii and the U.S.-affiliated islands is equivalent to the total EEZ surrounding the continental U.S. and Alaska. The vast extent of the area demands a high endurance, fast, multi-gear ship to minimize transit time among survey sites and trips by single-

purpose vessels. With an FRV, mid- and deep-water trawl surveys could be conducted on seamounts for the first time, a capability currently lacking, to provide new and critically important data on stocks that aggregate at seamounts. A quiet ship is essential for hydroacoustic fish and forage-base assessments, and for acoustic tracking of large pelagic species. Conducting research on highly migratory species from a quiet FRV will improve data precision and optimize compatibility with Japanese quiet FRVs during cooperative research. Fisheries research is now conducted from the TOWNSEND CROMWELL, but the ship is 35 years old, lacks needed capabilities, and should have long since been replaced due to its poor condition.

In the Gulf of Mexico/Caribbean ecosystem FRV time is needed to conduct long-term stock assessment surveys, including trawl, reeffish, marine mammal, longline and plankton surveys. The region has just replaced the unreliable CHAPMAN with a converted T-AGOS ship, the GORDON GUNTER, and completed major repairs on the 31 yr-old OREGON II. The area is contiguous with international waters of Mexico and the wider Caribbean, and joint, synoptic surveys must be conducted throughout the shared ecosystems to provide information at the stock level for interjurisdictional species. For example, stock assessments for coastal pelagics (e.g., mackerels, dolphin fish, and wahoo) must include data on Mexico's portion of the Gulf of Mexico to properly assess the status and condition of these stocks throughout their full ranges. Hydroacoustic surveys are not routinely conducted due to the lack of a quiet research platform. However, scientists are experimenting with using hydroacoustics in conjunction with trawl and reeffish surveys, and expanded use of this technology is anticipated. For example, a quiet ship with hydroacoutic capability is needed to conduct a first-time census of bluefin tuna as they migrate through discrete corridors through the area. Annual, comprehensive shark surveys, conducted cooperatively with neighboring scientists in U.S., Mexican, and Cuban waters will be initiated this year. Synoptic, large-scale, long-term studies such as these require the special features of a dedicated FRV.

Historically, only sperm whales and occasional fin whales were noted in the Gulf of Mexico, in addition to the coastal dolphin species. Recent synoptic surveys for marine mammals in the Gulf of Mexico have essentially redescribed the species diversity for mammals in the region, with species richness now over 20 species. It is now evident that large whales are common in this ecosystem. The primary calving grounds of two species, the right whale and humpback whale, are located here, and there have been predictable sightings of killer whales. Based on these findings, the frequency of large-scale, synoptic surveys for marine mammals must be increased beyond current levels to adequately monitor these protected species. Census surveys in conjunction with aerial surveys must be conducted using a quiet FRV with listening capability.

Work in the South Atlantic requiring FRV ship time includes surveys for South Atlantic sharks, groupers, and marine mammals. Trawling and ecological work in this ecosystem will continue through a contract with South Carolina and using chartered vessels. Interjurisdictional fisheries also exist here, including those which target sharks, bluefin tuna, and swordfish, making large-scale studies important for stock assessments.

Stock assessment surveys of regulated species use most of the available FRV DAS in the Northwest Atlantic ecosystem. A quiet, multi-capable ship is necessary for these surveys to ensure continuity of the data bases, and to allow tandem trawl and hydroacoustic studies to be conducted in conjunction with synoptic oceanographic sampling. A new initiative to increase the precision of assessments for small pelagic species (herring, mackerel, squids, and butterfish) has begun to help avoid the boom and bust cycle for the fisheries on these species. Because of the depth distribution of these species, a quiet FRV is absolutely necessary to minimize bias due to ship effects. Acoustically quiet vessels are also critical to assessments of many marine mammal stocks (e.g., harbor porpoise) designed to meet MMPA/ESA mission requirements. Studies of the associations of fish, invertebrates, and other species with habitat-related factors to identify EFH also require the use of quiet FRVs and a variety of remote sensing technologies. As the region's cod, haddock, and flounder fisheries are being rebuilt, it is urgent that high-quality assessment data be available to fisheries managers, so they can make informed adjustments to management strategies. The ALBATROSS IV and DELAWARE II are currently dedicated to this ecosystem. The ALBATROSS IV is 36 yrs-old and has recently undergone major repairs to prolong its service life. The DELAWARE II just un-

derwent a "Repair To Extend", which should extend its life by 10 years.

Reconciling Data Acquisition Needs with the Budget

No single option among those discussed above adequately addressed NOAA Fisheries' needs. Hence, the *Plan* integrates all of these components into a strategy to meet at-sea data requirements. The central philosophy of the *Plan* is to construct a core fleet of purpose-built, dedicated FRVs to meet the most demanding mission requirements. As new FRVs are built, calibrated and brought into the fleet, existing ships will be retired. Meantime, repairs will be made to existing vessels to ensure they will continue to provide a safe and effective platform for data collection until they can be replaced. Acoustic quieting on the new FRVs maximize the utility of hydroacoustic technology at its present state and creates the potential to capitalize on technological advances throughout the vessels' 30-yr life span. At the same time, charter vessels will play an increasingly important role in data acquisition.

Each new FRV will be capable of spending approximately 270 days per year at sea conducting research. Dividing the estimated 2,516 DAS annual requirement for quiet FRVs (Table 4) by the average annual capability of 270 DAS per ship yields 9.3 FRV ship-years of a combination of full- and part-time FRV time to accomplish these mission needs.

Four purpose-built, full-time FRVs will be built by NOAA. The President announced a commitment to construction of new FRVs and appropriate budgets will be submitted to accomplish this (Table 5).

NOAA Fisheries intends to explore expansion of its partnership with the UNOLS system and the private sector to address unmet needs with chartered vessels. A firm commitment to meeting the FRV shortfall in collaboration with UNOLS will provide the incentive to overcome the ship configuration and scheduling problems that currently limit the use of the UNOLS fleet. Communicating this opportunity to UNOLS now will provide the necessary lead time to incorporate fisheries missions into their own fleet modernization plan. Thus, charter DAS of non-FRVs must increase to support SFA guidance to increase bycatch research, reef fish assessments, Pacific groundfish assessments, and Pacific salmon research. Results of the data acquisition planning will be used to guide the scheduling and prioritization of missions to fall within budget constraints.

Data Acquisition Plan Review

An external review of the data and ship requirements was performed and the report was provided to NOAA in May, 1998.[14] The report concluded that construction of a core fleet of purpose-built vessels is a good approach, and that the FRV requirements development process is sound. The FRVs were described as outstanding platforms that will serve the nation extremely well as the core of a dedicated fisheries fleet for their full projected lifetime. The report also concluded that the vessels are not overspecified.

Further study of vessel acquisition, management, ownership, and operation was encouraged in the review, and NOAA Fisheries is now engaged in those studies. Partnerships with UNOLS, individual academic institutions, other government organizations and the private sector were strongly endorsed in the report. This *Plan* reflects NOAA Fisheries' intent to expand its partnership base to meet its vessel (both FRV and other) needs.

SUMMARY

The *Data Acquisition Plan* incorporates a number of measures to meet NOAA Fisheries data needs over the next five years. Partnerships with academic and commercial fleet operators will play a growing role. Replacement of the existing fleet with the new FRVs will ensure continuity of long-term data bases, and will enable NOAA Fisheries to capitalize on technological advances in tools such as hydroacoustics as they become available. Timely implementation of the *Plan* is essential to meet the increasing demand for high-quality, fishery-independent data. Delays would require consideration of additional repair-to-extend programs or costly conversions of suboptimal vessels as short-term solutions to the attrition of aging vessels in the existing fleet.

NOAA Fisheries bears the stewardship responsibility for the largest EEZ in the world, and to perform that mission, it must have the proper tools. New legislation, management philosophies and scientific advances have created new opportunities to improve fisheries management in the

...a core fleet of four FRVs will be constructed

Fiscal Year	2000	2001	2002	2003	2004
FRV 1	Construction			Deploy	
FRV 2		Construction			Deploy
FRV 3			Construction		
FRV 4				Construction	
Charter DAS	1,759	1,759	1,925	1,925	2,076
Existing Fleet DAS	2,015	2,015	1,849	2,119	1,995

Table 5.

Plan milestones for the five-year period beginning in FY2000.

U.S. Providing appropriate support will enable NOAA Fisheries to capitalize on these opportunities to the economic benefit of the Nation and integrity of our living marine ecosystems.

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